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Shear Strength Properties of Embedded Wood Attacked by Brown Rot Fungi

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Abstract

There are a lot of traditional wooden houses, temples and shrines in Japan. These traditional wooden structures have already been standing for a long time. Many of these structural members and joints have suffered from biodeteriorations induced by fungi, termites and so on. It is difficult to know the residual strength of decayed structural members and joints. Therefore it is very important to evaluate the residual strength of structural members and joints for house in use for long term safety, and decide when repair and replacement of the members should be undertaken. The objective of this study is to evaluate the shear strength of nail joints attacked by fungi, which are often used in the wooden houses. In this study, we prepared the partial decayed specimens embedded by nails, and evaluated the shear strength.

Those specimens were locally attacked by brown rot fungi (*Fomitopsis palustris*) for 7 weeks and evaluated the shear strength. In the case of steel nail joint, the shear strength of the decayed wood was higher than those of the sound wood. On the other hand, the shear strength of stainless steel nail joint was slightly decreased by the fungus attack.

Keywords: residual strength, brown rot fungi, nails, shear property, biodeterioration.

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1. Introduction

It is important to continue to use the wooden house for the environmental protection. In Japan, there are a lot of traditional wooden houses, temples and shrines. Therefore it is seemed that to increase the use of these constructions become the environmental contribution. In particular it is important to increase in the general old houses except the houses of cultural assets, temples and shrines. Some of structural members and joints have been damaged by the biodeteriorations induced by the fungi, the termites and so on, however these wooden houses already use steel connectors for the reinforcement and repairing of members or joints. In this case, it is very important to evaluate the residual strength of structural members and joints for houses in use with long term safety, and decide when repair or where replace of the members and joints should be undertaken, because. It is difficult to know the survival strength of members and joints.

The objective of this study is to evaluate the shear strength of nail joints attacked by fungi, which are often used in the wooden houses. Therefore the newly method of making specimens decayed partially by brown rot fungi (*Fomitopsis palustris*) was examined, and the shear strength properties of nail joint using the decayed specimens was investigated.

2. Materials and Methods

2.1. Materials

Sugi (*Cryptomeria japonica*) was cut into specimens of 250 mm length with a cross-section of 50x50 mm, and detail of specimen was shown in Figure 1. The specimens were dried to the moisture content of about 12%, cleaned with alcohol, and inserted with nails before decayed by fungi. In this study, two types of nails which made from steel (ϕ2.45 mm) and stainless steel (ϕ2.3 mm) 45mm in length were used, and both nails were driven 42 mm in depth from surface of sapwood or heartwood. Therefore one specimen has four nails. In addition the 3 mm gaps were used to connect with specimens with the testing jig.

Ten specimens were decayed by fungi and the other five specimens were without damage. The specimens were named; driven the steel nail from sapwood is SSS, driven steel nail from heartwood is SSH, driven stainless nail from sapwood is SUSS, and driven stainless nail from heartwood is SUSH.

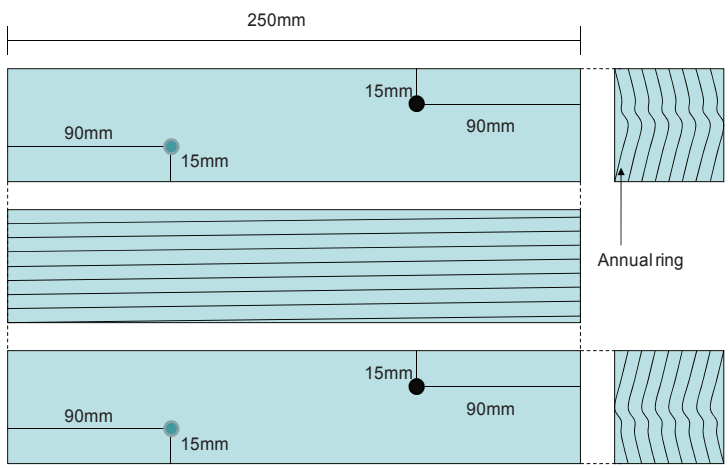


Figure 1: Overview of specimen (gray dot: steel nail, black dot: stainless steel nail)

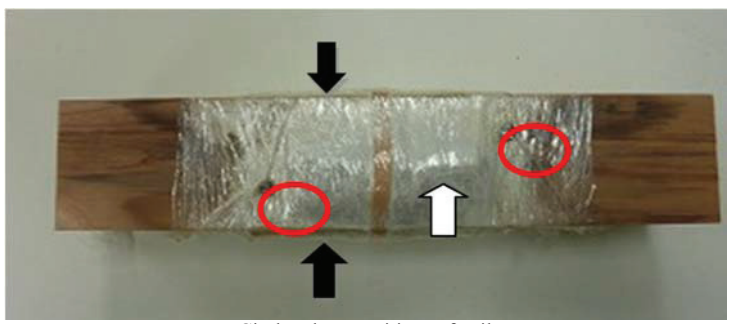
2.2. Preparing partial decayed specimens

The method of making specimens which was decayed partially by brown rot fungi was proposed, as shown in table 1. The specimens were continuously attacked by brown rot fungi for 7 weeks. Figure 2 shows the state of the specimen.

Table 1: Method of preparing specimens which is deteriorated partially by brown rot fungi

	Contents
1	Autoclave sterilize the vermiculite culture containing liquid culture (B culture*), the nonwoven fabric bag, and wet paper towel (wetting mat).
2	Inoculate brown rot fungi *Fomitopsis palustris* on the sterilized vermiculite culture.
3	Pack 6 g of inoculated vermiculite culture into the sterilized nonwoven fabric bag (fungal mat).
4	Brush all surface of specimen with Alcohol.
5	Put the fungal mat on the nailed face of specimen, and the wetting mat on the side faces. Wrap around the mats with PVC film to keep wet condition (Figure 2).
6	Cultivate the wrapped specimens at 27 degrees, RH83% for 7 weeks, supplying with 10ml water to each mat every two weeks.

*:Malt extract 1%, Glucose 2.5%, Peptone 0.5%, KH_2PO_4 0.3%, $MgSO_4$ 0.2%



Circles show positions of nail
White arrow : Fungal mat,
Black arrow : Wetting mat
Figure 2: Condition of the specimens

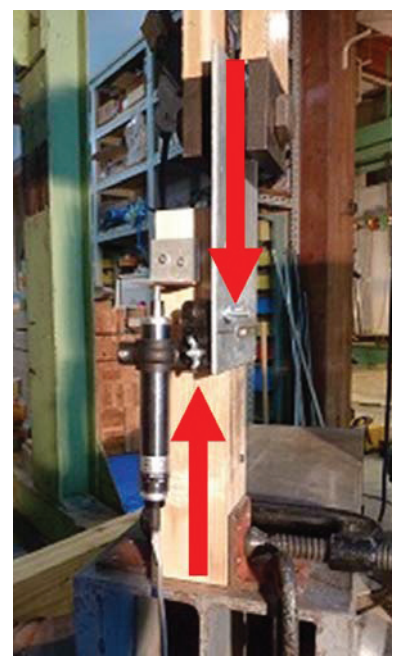


Figure 3: Apparatus of nail shear test

2.3. Shear test

Single shear method by compressive test type was adopted to evaluate the shear strength properties of nail joints attacked by fungi. It was tested by universal testing machine with loading speed of 2mm/min in Figure 3. The load and slip displacement were measured by load cell and transducer, respectively.

3. Results and Discussions

3.1. Method of making specimens

The damages of surface of sapwood and heartwood are shown in Figure 4 and 5, respectively. The fungal attacked surface was softened and cracked in both specimens, sapwood and heartwood. In all specimens, the fungal attacked area corresponded to the wrapped area, and both end surfaces of specimen were kept sound condition. Our decay method has enabled the decayed specimen to fix firmly on the apparatus and carry out the nail shear test. The cracks and softening in sapwood was severer than in heartwood, thus it was verified that heartwood was more durable than sapwood.

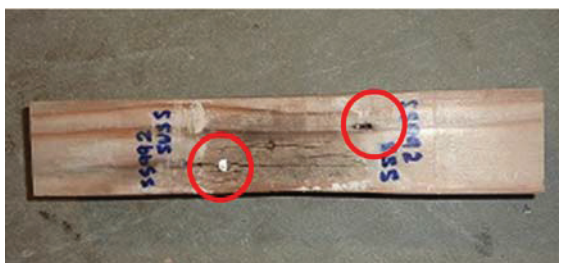


Figure 4: Failure mode of sapwood face
(circles show positions of nail)

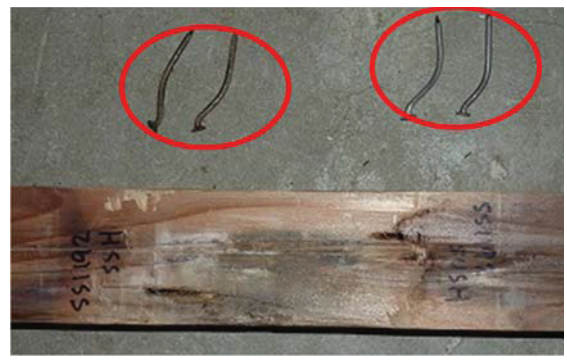


Figure 5: Failure mode of heartwood face
(left circle; steel nail, right; stainless steel nail)

3.2. Shear strength properties

Many of steel nail heads went away by damage of stain (Figure 4), however stainless steel nail heads did not go away. There were no differences in the failure mode of each nails inserted from sapwood and heartwood.

Relationship between load and slip displacement obtained from decayed specimens and sound specimens are shown in Figure 6 and 7, respectively. In this paper, the strength means the yield strength. It seems that the decayed specimens inserted steel nails were stronger than the sound ones though the strength and stiffness of decayed specimens inserted stainless steel nail slightly decrease. It seems that the stain of nails affected the strength properties.

It was indicated that the specimens inserted nails from surface of heartwood was slightly stronger than from surface of sapwood, and for that reason, it was thought that the damage in mechanical properties caused by decaying from sapwood was faster than that by decaying from heartwood. It is important to prepare specimens attacked by fungi for a long term, because it is necessary to evaluate the shear strength properties of wooden members with steel or stainless steel nails with larger fungal damages.

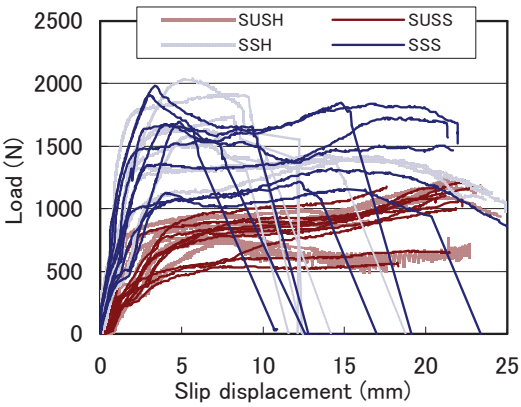


Figure 6: Relationship between load and slip displacement obtain from damaged specimens

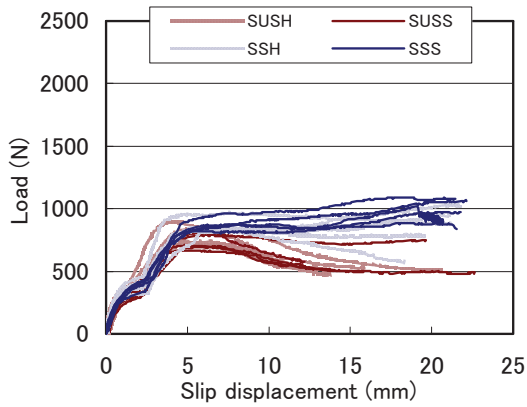


Figure 7: Relationship between load and slip displacement obtain from undamaged specimens

4. Conclusions

The partial decayed specimens embedded by nails by brown rot fungi were prepared, and were evaluated the shear strength properties. The results are as following,

1. Our decay method has enabled the decayed specimen to fix firmly on the apparatus and carry out the nail shear test. Because the fungal attacked area was restricted in wrapped area, and both end surfaces of specimen were kept sound condition.
2. The shear strength properties of decayed specimens inserted the steel nail were stronger than the sound ones. And it seems that the stain of nails affected the strength properties.
3. The shear strength properties of decayed specimens inserted the stainless steel nail showed slightly decreasing compared with sound ones.

In the future, it is necessary to prepare the decayed specimens of different damage for shear or embedding test and to clarify when repair and/or where replace of the decayed members and joints.

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